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(54) **THREE-FUNCTION REFLOWABLE CIRCUIT PROTECTION DEVICE**

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USPC 337/142, 152, 153, 297, 401, 402, 337/407–409
See application file for complete search history.

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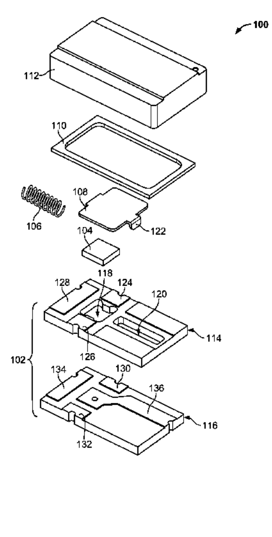
(57) **ABSTRACT**

A circuit protection device is configured to protect circuit elements under any one of the following three activation conditions: an over current condition, an over temperature condition, and an activation control current received by a heater element. The circuit element includes first and second electrodes, and the heater element. A sliding contact is connected by a sensing element to the first electrode, second electrode, and heater element, thereby bridging and providing a conductive path between each. A spring element is held in tension by, and exerts a force against, the sliding contact. Upon detection of any one of three activation conditions, the sensing element releases the sliding contact and the force exerted by the spring element moves the sliding contact to another location on the substrate at which the sliding contact no longer provides a conductive path between the first electrode, second electrode, and heater element.

20 Claims, 9 Drawing Sheets



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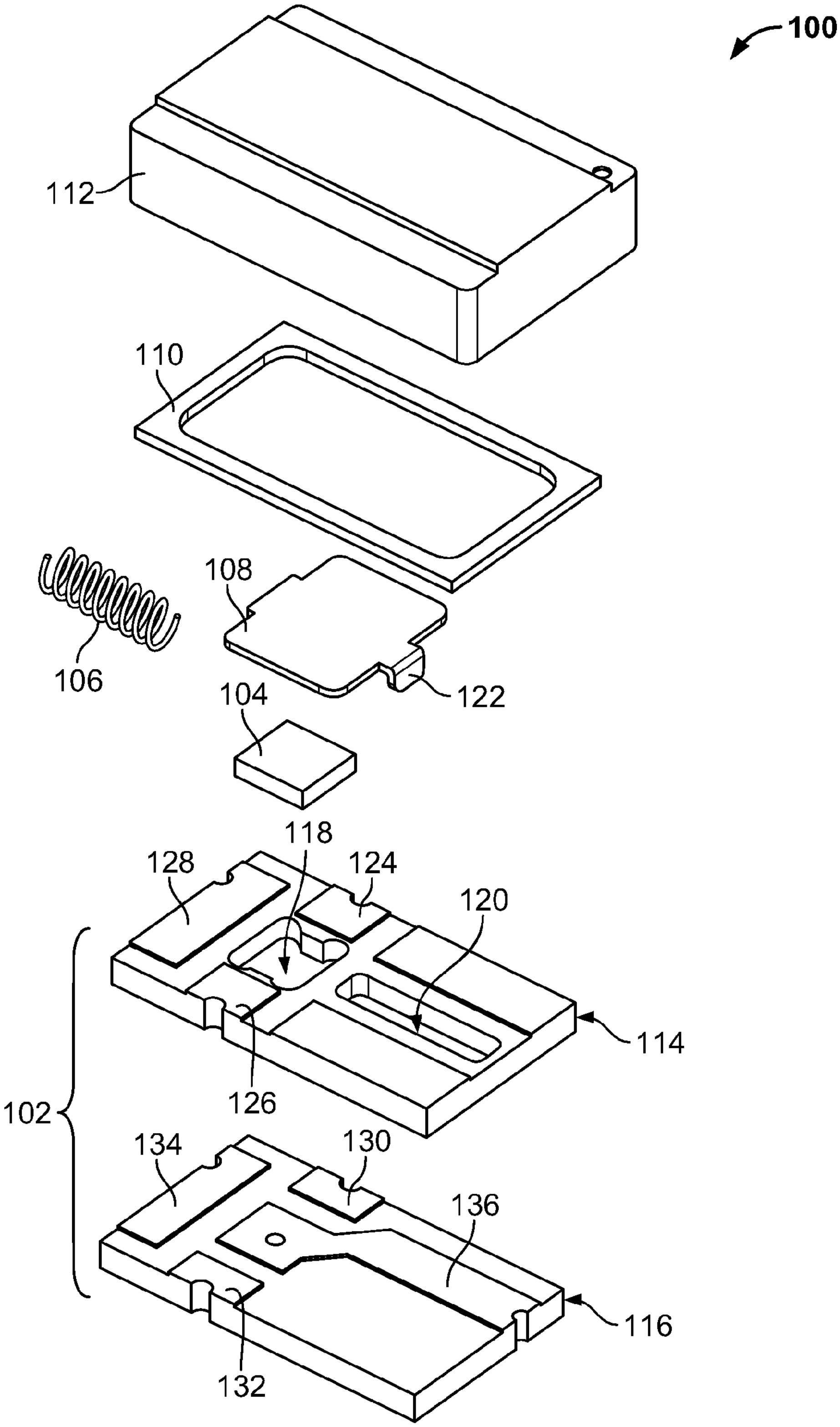
100
112
110
108
106
122
104
118
128
124
120
114
126
102
134
130
136
116
132

Figure 1

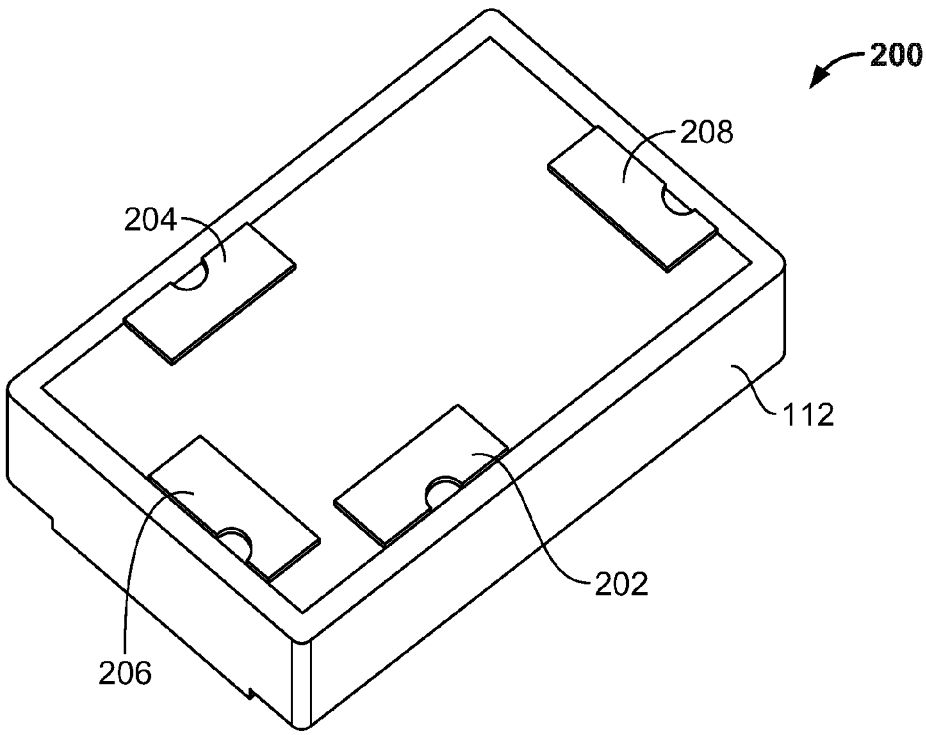

Figure 2a

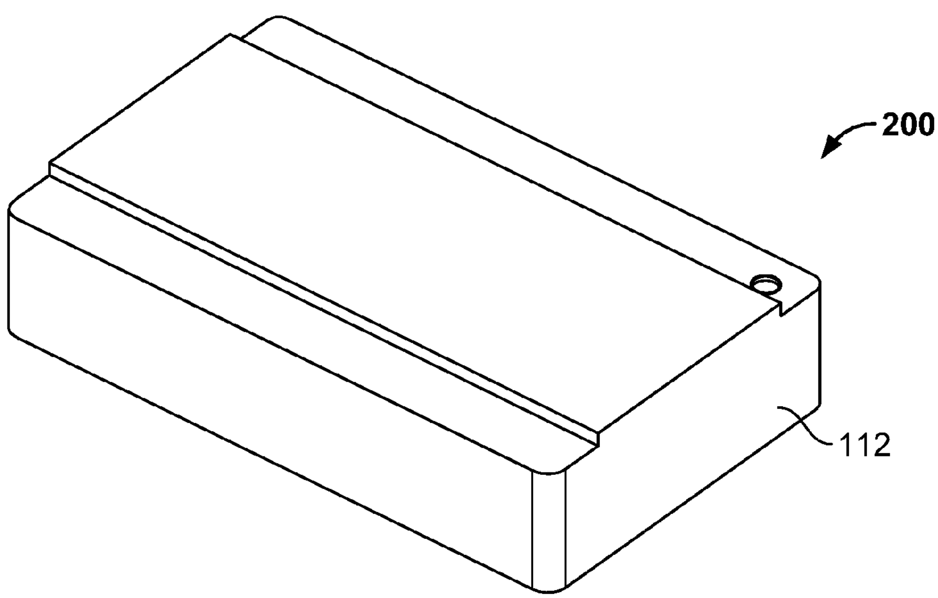

Figure 2b

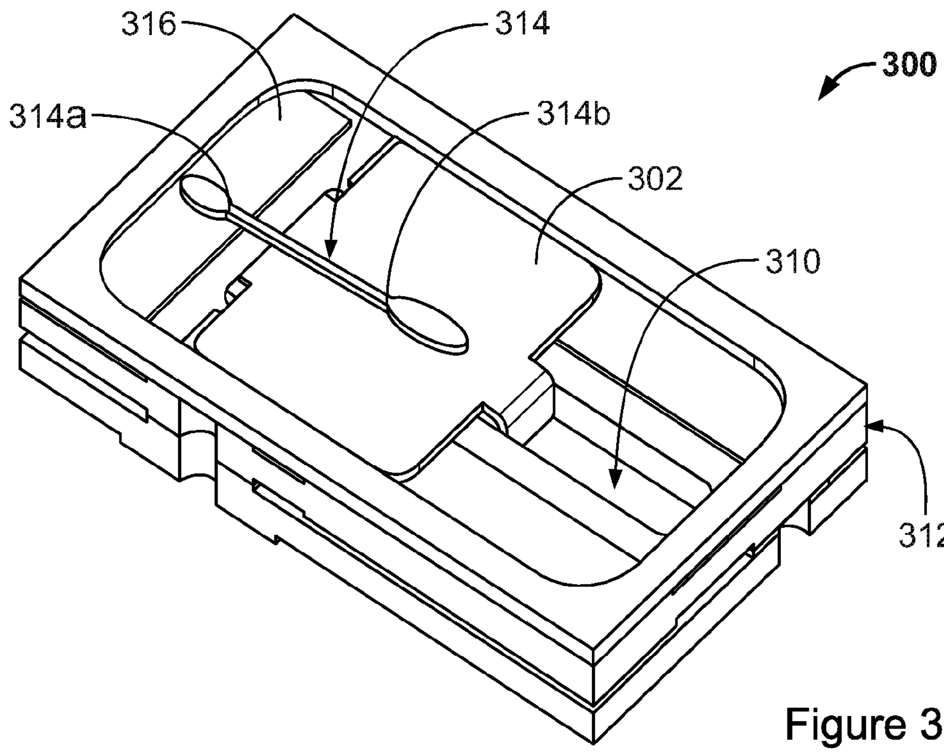

Figure 3a

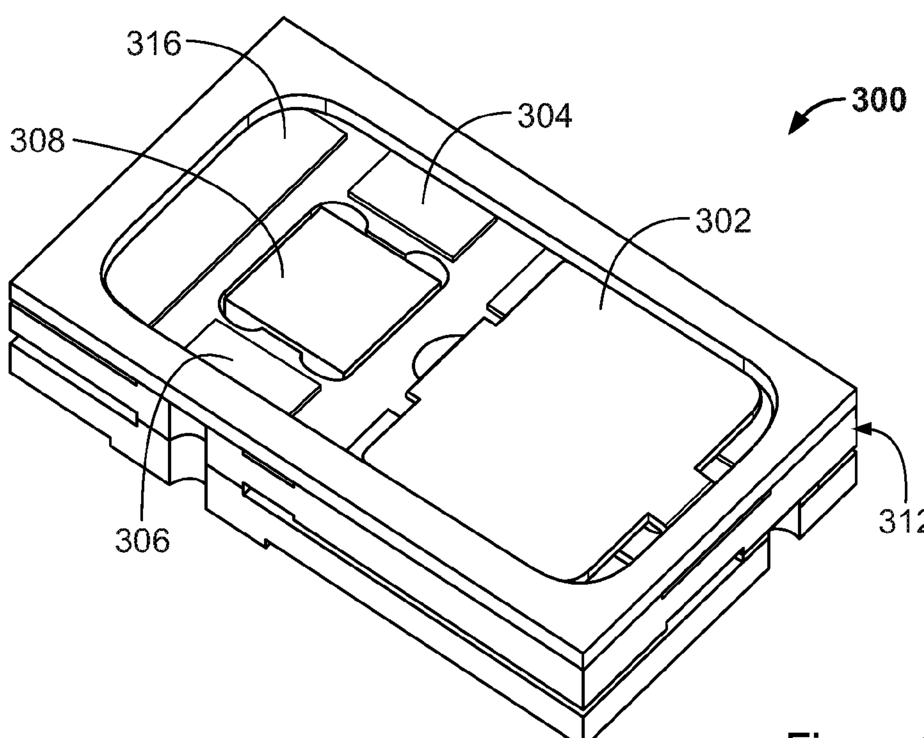

Figure 3b

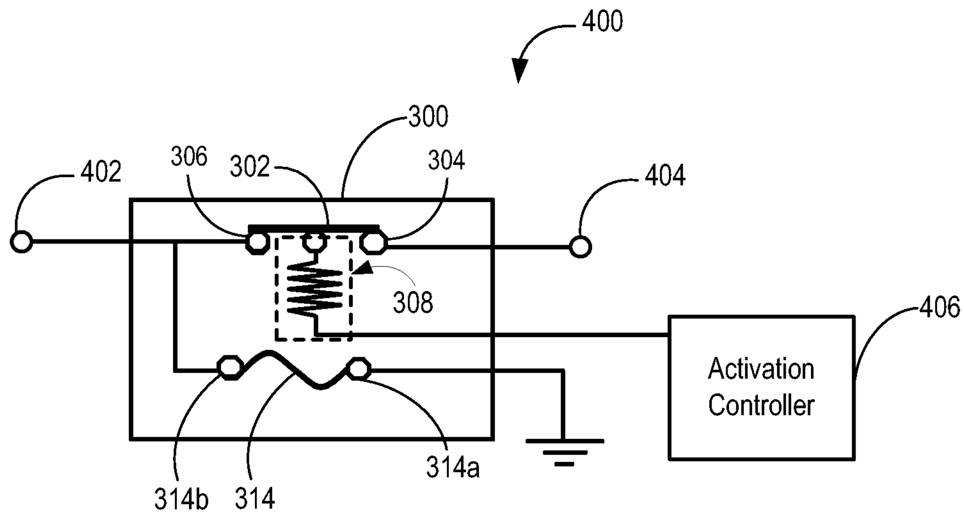
400
300
402
306
302
304
404
308
406
Activation
Controller
314b
314
314a

Figure 4

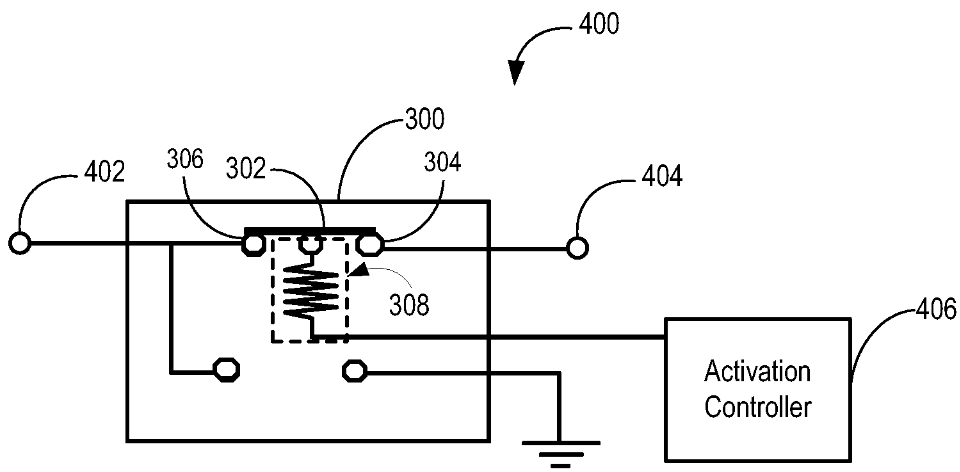

Figure 5

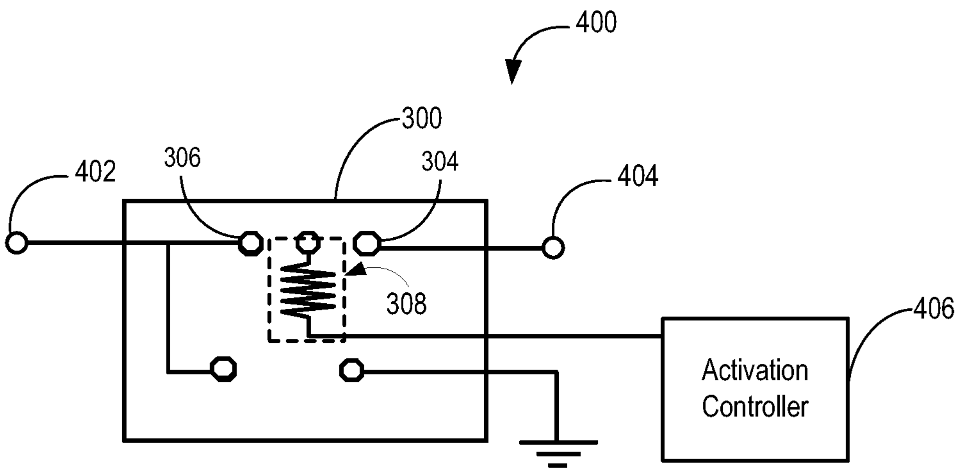

Figure 6

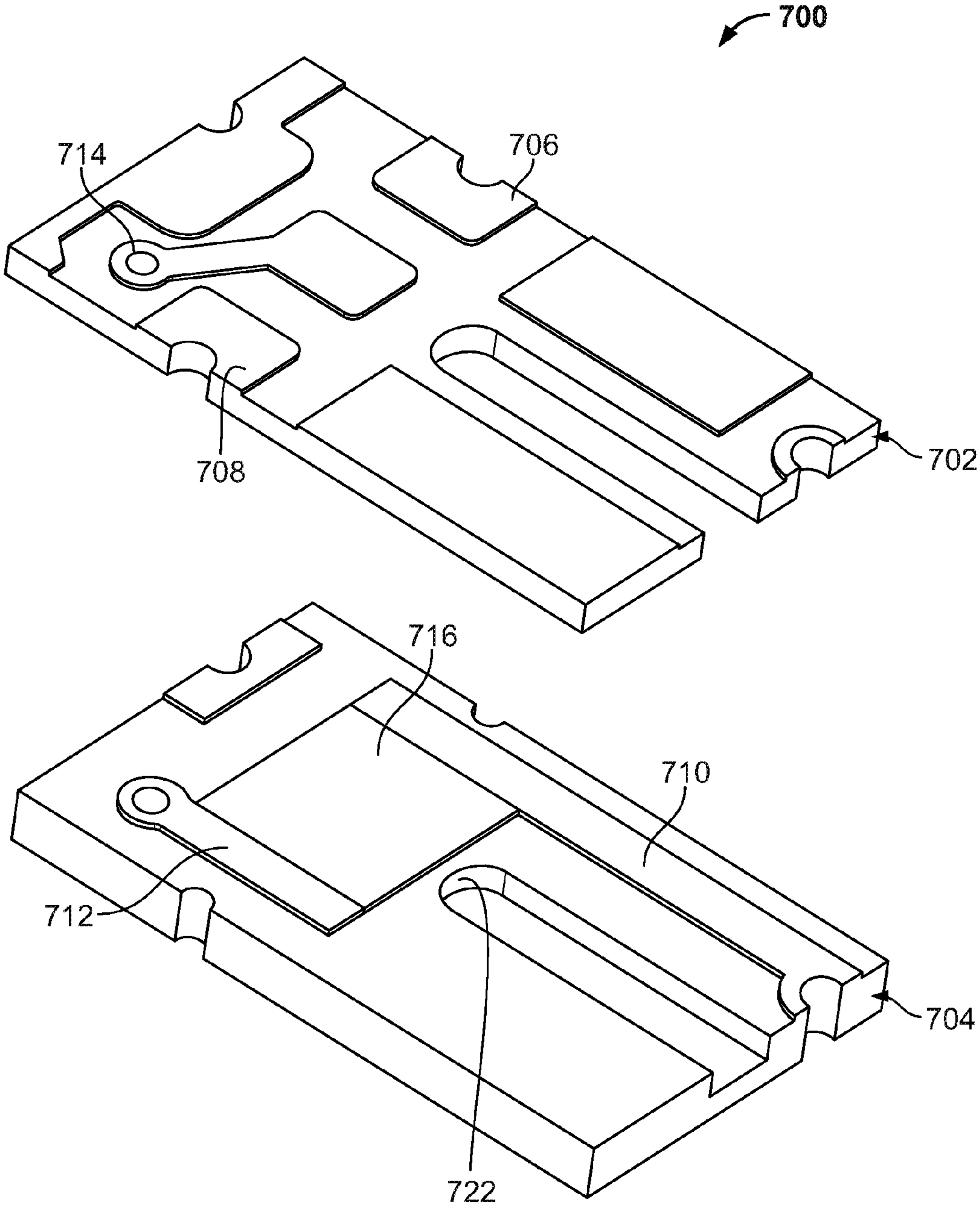

Figure 7

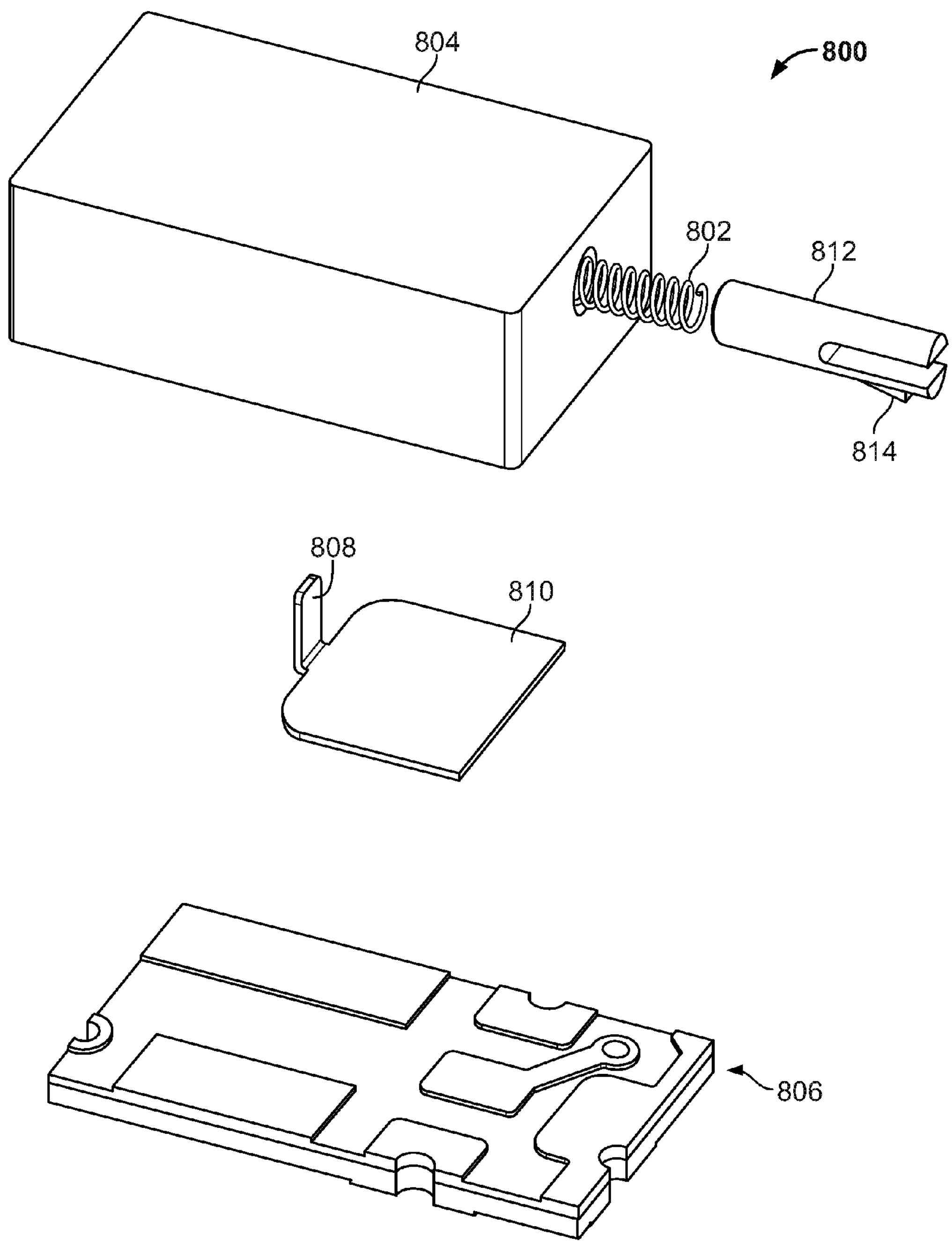

Figure 8

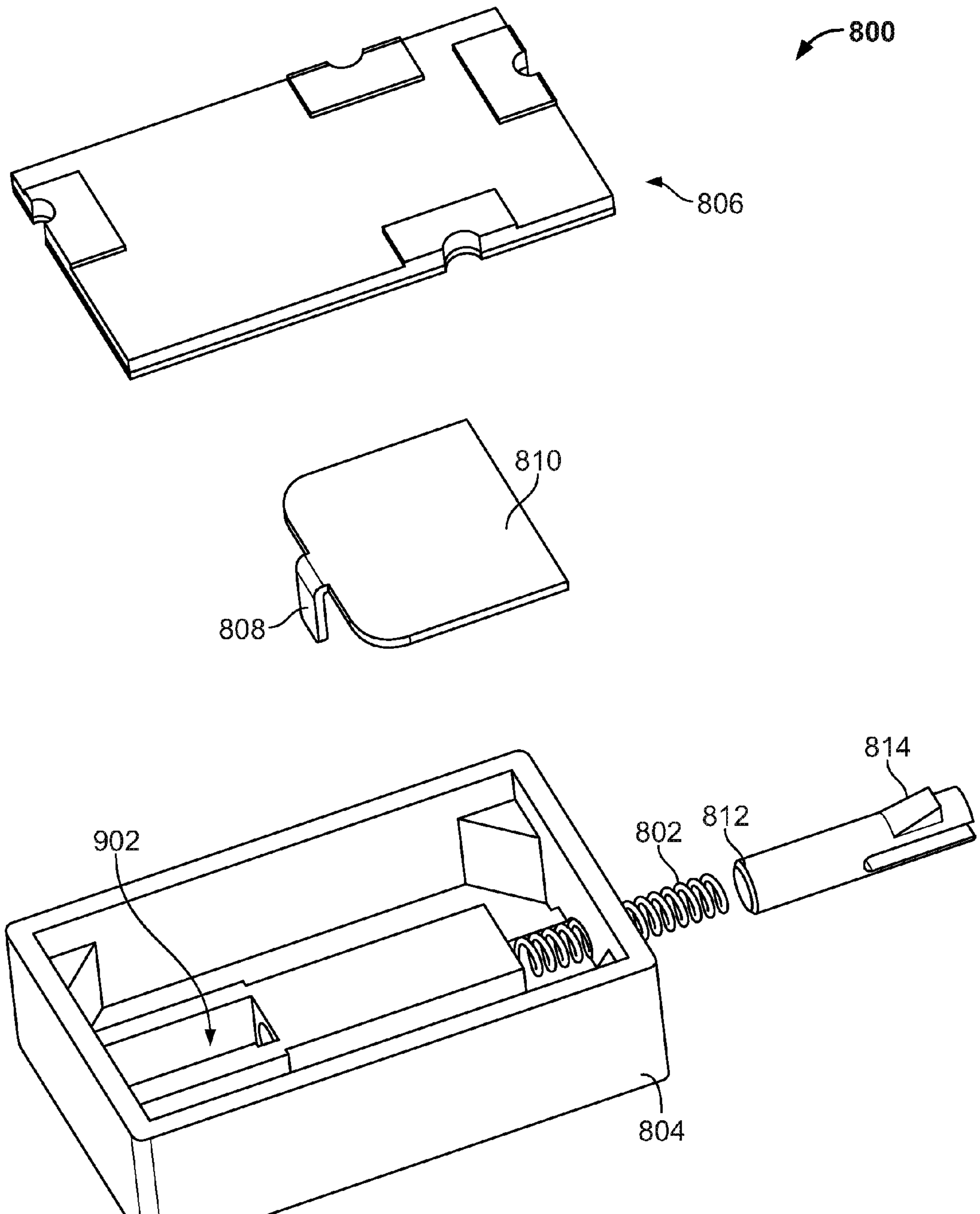

Figure 9

THREE-FUNCTION REFLOWABLE CIRCUIT PROTECTION DEVICE

BACKGROUND

I. Field

The present invention relates generally to electronic protection circuitry. More, specifically, the present invention relates to an electrically activated three-function surface mount circuit protection device.

II. Background Details

Protection circuits are often times utilized in electronic circuits to isolate failed circuits from other circuits. For example, the protection circuit may be utilized to prevent electrical or thermal fault condition in electrical circuits, such as in lithium-ion battery packs. Protection circuits may also be utilized to guard against more serious problems, such as a fire caused by a power supply circuit failure.

One type of protection circuit is a thermal fuse. A thermal fuse functions similar to that of a typical glass fuse. That is, under normal operating conditions the fuse behaves like a short circuit and during a fault condition the fuse behaves like an open circuit. Thermal fuses transition between these two modes of operation when the temperature of the thermal fuse exceeds a specified temperature. To facilitate these modes, thermal fuses include a conduction element, such as a fusible wire, a set of metal contacts, or set of soldered metal contacts, that can switch from a conductive to a non-conductive state. A sensing element may also be incorporated. The physical state of the sensing element changes with respect to the temperature of the sensing element. For example, the sensing element may correspond to a low melting metal alloy or a discrete melting organic compound that melts at an activation temperature. When the sensing element changes state, the conduction element switches from the conductive to the non-conductive state by physically interrupting an electrical conduction path.

In operation, current flows through the fuse element. Once the sensing element reaches the specified temperature, it changes state and the conduction element switches from the conductive to the non-conductive state.

One disadvantage of some existing thermal fuses is that during installation of the thermal fuse, care must be taken to prevent the thermal fuse from reaching the temperature at which the sensing element changes state. As a result, some existing thermal fuses cannot be mounted to a circuit panel via reflow ovens, which operate at temperatures that will cause the sensing element to open prematurely.

Thermal fuses described in U.S. patent application Ser. No. 12/383,595, filed Mar. 24, 2009 and published as US 2010/0245022, and U.S. application Ser. No. 12/383,560, filed Mar. 24, 2009 and published as US 2010/0245027—the entirety of each of which are incorporated herein by reference—address the disadvantages described above. Further disadvantages include size and versatility. Circuit protection devices are often too tall to meet the height constraints for circuit board mounted devices. Circuit protection devices also often do not provide the versatility to allow the circuit protection device to activate under all the conditions necessary to adequately protect the circuit. While progress has been made in providing improved circuit protection devices, there remains a need for improved circuit protection devices.

SUMMARY

A circuit protection device is configured to protect circuit elements under any one of the following three activation conditions: an over current condition, an over temperature condition, and an activation control current received by a heater element. The circuit protection device includes a substrate with first and second electrodes connected to the circuit to be protected. The circuit protection device also includes a heater element positioned between the first and second electrodes. A sliding contact is connected by a sensing element to the first electrode, second electrode, and heater element, thereby bridging and providing a conductive path between each. A spring element is held in tension by, and exerts a force parallel to a length of the substrate against, the sliding contact. The connection provided by the sensing element between the sliding contact and the first electrode, second electrode and heater element resists the force exerted by the spring element. Upon detection of any one of the activation conditions, the sensing element releases the sliding contact and the force exerted by the spring element moves the sliding contact to another location on the substrate at which the sliding contact no longer provides a conductive path between the first electrode, second electrode, and heater element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded view of an unassembled exemplary three-function reflowable circuit protection device.

FIG. **2***a* is a bottom view an assembled circuit protection device.

FIG. **2***b* is a top view the assembled circuit protection device shown in FIG. **2***a*.

FIG. **3***a* is a circuit protection device with the sliding contact in the closed position.

FIG. **3***b* is the circuit protection device of FIG. **3***a* with the sliding contact in the open position.

FIG. **4** is a schematic representation of an exemplary battery pack circuit to be protected by a circuit protection device before the restraining element is blown.

FIG. **5** is a schematic representation of the circuit of FIG. **4** with the restraining element blown and the sliding contact in the closed position.

FIG. **6** is a schematic representation of the circuit of FIG. **5** with the sliding contact in the open position.

FIG. **7** is another embodiment for the substrate of a three-function reflowable circuit protection device.

FIG. **8** is top view of another embodiment of a three-function reflowable circuit protection device.

FIG. **9** is bottom view of the three-function reflowable circuit protection device shown in FIG. **8**.

DETAILED DESCRIPTION

FIG. **1** is an exploded view of an unassembled exemplary three-function reflowable circuit protection device **100**. The circuit protection device **100** includes a substrate **102**, a heater element **104**, a spring element **106**, a sliding contact **108**, and a spacer **110**. The circuit protection device **100** may also include a cover **112**.

The substrate **102** may include a printed circuit board (PCB). For the sake of explanation, the substrate **102** is described as a multilayer PCB including a top PCB **114** and a bottom PCB **116**. It will be understood that the substrate **102** may also be fabricated as a single layer.

The top PCB **114** includes an opening **118** that receives the heater element **104**. The height of the top PCB **114** may be set to allow the top of the heater element **104**, when placed in the opening **118**, to be co-planar with the top surface of the substrate **102**, i.e., with the top surface of the top PCB **114**. In another embodiment shown in FIG. **7** and described in more detail below, the heater element **104** may be laid up into the substrate **102** during the fabrication process. In this example, the substrate **102** may not include the opening **118**.

The top PCB **114** may also include another opening **120** for receiving a cantilever portion **122** of the sliding contact **108**. The opening **120** in FIG. **1** extends parallel to the length of the substrate **102**, allowing the sliding contact **108** to slide in a direction parallel to the length of the substrate **102**. In another embodiment shown in FIGS. **8-9** and described in more detail below, the cantilever **122** may extend away from the substrate **102** towards the cover **112**. In this example, substrate **102** may not include the opening **120**.

The top PCB **114** includes pads/electrodes, **124**, **126** and **128**. The electrodes **124** and **126** may be positioned on opposite sides of the opening **118** along a width of the top PCB **114**. The electrode **128** may be positioned on a side of the opening **118** opposing the side the opening **120** is located on opposite sides of the opening **118**. As shown in FIGS. **3***a*-**3***b*, the sliding contact **108** bridges the electrodes **124** and **126** and the heater element **104** when the sliding contact **108** is in a ready or closed position, thus facilitating an electrical connection between the heater element **104**, electrode **124** and electrode **126**.

The bottom PCB **116** includes pads **130**, **132** and **134** corresponding to the location of the electrodes **124**, **126** and **128**, respectively, of the top PCB **114**. The bottom PCB **116** may also include pad **136** corresponding to the location of the heater element **104**. As shown in FIG. **2***a*, the bottom side of the bottom PCB **116** includes terminals corresponding to the pads **130**, **132**, **134** and **136** for connection to the circuit to be protected.

As noted, the heater element **104** fits into the opening **118** in the substrate **102**. The heater element **104** may also constitute another electrode of the circuit protection device **100**. The heater element **104** may be a positive temperature coefficient (PTC) device, such as the PTC device disclosed in U.S. application Ser. No. 12/383,560, filed Mar. 24, 2009, the entirety of which is incorporated herein by reference. Other heater elements, such as a conductive composite heater, that generate heat as a result of current flowing through the device, may be utilized in addition to or instead of the PTC device. In another example, the heater element **104** may be zero temperature coefficient element or constant wattage heater. As shown in FIG. **7**, in another embodiment the heater element may also be a thin-film resistor or heating device laid up into the substrate during a PCB process.

The sliding contact **108** may be a conductive and planar element with the cantilever portion **122**. The cantilever portion **122** fits into the opening **120**. The spring element **106** is located between the cantilever **122** and a side of the opening **120**. The sliding contact **108** may be fused to the heater element **104** and electrodes **124**, **126** with, for example, a low melt-point sensing element (not shown). When the sensing element changes state, e.g., melts at a threshold temperature, the sliding contact **108** is no longer fused to the electrodes **124**, **126** and heater element **104**, and the spring element **106** expands and pushes the sliding contact **108** down the channel **120**. The sensing element may thus provide mechanical, and electrical, contact between the sliding contact **108** and the electrodes **124**, **126** and heater element **104**.

The sensing element may be, for example, a low melt-point metal alloy, such as solder. For the sake of explanation, the sensing element is described herein as a solder. It will be understood that other suitable materials may be used as the sensing element such as, for example, a conductive thermoplastic having a softening point or melting point.

With the sliding contact **108** soldered to the heater element **104** and electrodes **124**, **126**, the spring element **106** between the cantilever **122** and the side of the opening **120** is held in a compressed state. When the solder that holds the sliding contact **108** to the heater element and electrodes **124**, **126** melts, the spring element **106** is allowed to expand, pushing against the cantilever **122** and causing it to slide down the opening **120**, which in turn pushes the sliding contact **108** off the heater element **104** and electrodes **124**, **126**. In this manner, the electrical connection between the heater element **104**, electrode **124** and electrode **126** is broken. FIGS. **3***a* and **3***b*, described below, show a circuit protection device in a closed and an open position, respectively.

The spring element **106** may be a coil spring made of copper, stainless steel, plastic, rubber, or other materials known or contemplated to be used for coil springs. The spring element **106** may be of other compressible materials and/or structures known to those of skill in the art. For the sake of explanation, the spring element **106** is described as being held under tension in a compressed state by the sliding contact **108**. It will be understood that a spring element may also be configured to be held under tension in an expanded or stretched state, such as if the spring element comprises an elastic material. In this example, when an activation condition is detected and the solder melts, the spring element may pull the sliding contact off a heater element and electrodes of the substrate.

The circuit protection device **100** is configured to open under at least three conditions. The solder can be melted by an over current condition, i.e., by a current through electrodes **124** and **126**. When a current passing through the electrodes **124** and **126** reaches a threshold current, i.e., a current that exceeds a designed hold current, Joule heating will cause the solder to melt, or otherwise lose resilience, and the sliding contact **108** to move to the open position by being pushed open by the spring element **106**.

The solder can be melted by an over temperature condition where the temperature of the device **100** exceeds, such as by an overheating FET or high environmental temperatures, the melting point of the solder holding the sliding contact **108** to the electrodes **124**, **126** and the heater element **104**. For example, the ambient temperature surrounding the circuit protection device **100** may reach a threshold temperature, such as 140° C. or higher, that causes the solder to melt or otherwise lose resilience. After the solder melts, the sliding contact **108** is pushed down the channel **120** and into an open position, thus preventing electrical current from flowing between the electrodes **124**, **126** and the heater element **106**.

The solder can also be melted by a controlled activation condition where the heater element **104** is activated by a control current supplied by the circuit into which the circuit protection device **100** is installed. For example, the circuit protection device may pass a current to the heater element **104** upon detection of an overvoltage in the circuit, causing the device to act as a controlled activation fuse. As the current flowing through the heater element **104** increases, the temperature of the heater element **104** may increase. The increase in temperature may cause solder to melt, or otherwise lose resilience, more quickly, resulting in the sliding contact **108** moving to an open position.

The circuit protection device **100** also includes a restraining element (not shown) that holds the sliding contact **108** in the closed position during reflow. During a reflow process, the solder holding the sliding contact **108** to the heater element **104** and electrodes **124**, **126** can melt, which would result in the sliding contact **108** moving to the open position due to the force of the compressed spring **106**. For example, the melt point of the solder may be approximately 140° C., while the temperature during reflow may reach more than 200° C., for example 260° C. Thus, during reflow the solder would melt, causing the spring element **106** to prematurely move the sliding contact **108** to the open position.

To prevent the force applied by the spring element **106** from opening the circuit protection device **100** during installation, the restraining element may be utilized to maintain the holding sliding contact **108** in place and resist the expansion force of the spring **106**. After the reflowable thermal fuse is installed on a circuit or panel and passed through a reflow oven, the restraining element may be blown by applying an arming current through the restraining element. This in turn arms the reflowable thermal fuse.

A spacer **110** may be placed on the substrate **102**. The spacer **100** is an insulating material, such as a ceramic, polymeric, or glass, or a combination of thereof. For example, the spacer **100** may be made of a fiber or glass-reinforced epoxy. The spacer **100** includes an opening that forms a channel that allows the sliding contact **108** to slide under the conditions discussed above. The spacer **110** may have a height slightly greater than a height of the sliding contact **108** such that when the cover **112** is placed on the circuit protection device **100**, the underside of the cover abuts with the spacer **110**, allowing the sliding contact **108** to slide freely and avoiding any friction between the sliding contact **108** and the cover **112**.

Described below is an exemplary process for assembling the circuit protection device **100**. The substrate **102** may be fabricated by a PCB panel process, where circuit board pads form primary terminals, and plated vias make the connection from these terminals to surface mount pads. Slots may be cut using known drill and router processes. As an alternative, discrete, injection-molded parts with terminals that are insert-molded, or installed in a post-molding operation, may be used.

After the substrate **102** is fabricated and patterned, the heater element **104** may be installed in the substrate **102**, such as by soldering the bottom of the heater element **104** to the substrate **102**. The spring element **106** is inserted into the channel **120**. The sliding contact **108** is inserted and slid to place the spring element **106** in a compressed state between the cantilever **122** and a side of the channel **120**. The sliding contact **108** is soldered to the heater element **104** and the electrodes **124**, **126**.

The restraining element is attached to the sliding contact **108** on one end, and to the electrode **128** on the other end. Alternatively, one end of the restraining element may be attached to the sliding contact **108** before the sliding contact is soldered to the heater element **104** and electrodes **124**, **126**. In this example, the other end of the restraining element is attached to the electrode **128** after soldering of the sliding contact **108**. The restraining element may be attached by resistance welding, laser welding, or by other known welding techniques.

The spacer **110** may then be placed on top of the substrate **102**, the opening within the spacer having a width sufficient for the sliding contact **108** to fit within. The cover **112** may then be installed to keep the various parts in place.

FIGS. **2***a*-**2***b* show bottom and top views, respectively, of an assembled circuit protection device **200**. The bottom of the circuit protection device may include terminals **202**, **204**, **206**, **208** that facilitate electrical connection of the electrodes **124**, **126**, **128** and the heater element **106**, respectively, to external circuit board elements. In this manner the terminals **202**, **204**, **206**, **208** may be utilized to mount the circuit protection device **200** to a surface of a circuit panel (not shown) and bring the heater element **106**, electrodes **124**, **126**, **128** into electrical communication with circuitry outside of the device **200**.

In order to achieve a low profile, the height of the circuit protection device **200** may be 1.5 mm or less. The width of the circuit protection device **200** may be 3.8 mm or less. The length of the circuit protection device **200** may be 6.0 mm or less. In one embodiment, the circuit protection device may be 6.0 mm×3.8 mm×1.5 mm. Due to the expansion force of the spring element being parallel to the plane of the substrate surface, which results in the sliding contact also sliding parallel to the plane of the substrate, a substantially thin circuit protection device **200** is achieved.

FIGS. **3***a*-**3***b* show a circuit protection device **300** with the sliding contact **302** in the closed and open positions, respectively. In the closed position the sliding contact **302** bridges and provides an electrical connection between the electrodes **304**, **306** and the heater element **308**. In the open position, when the solder holding the sliding contact **302** to the electrodes **304**, **306** and heater element **308** melts, the force of an expanding spring element pushes the sliding contact **302** down the channel **310** in the substrate **312**, severing the electrical connection between the electrodes **304**, **306** and heater element **308**. As discussed above, the circuit protection device **300** is a three-function reflowable thermal fuse that is configured to open under three conditions: over current, over temperature, and controlled activation.

FIG. **3***a* also shows the restraining element **314** discussed above. The restraining element **314** may be a welded, fusible restraining wire that holds the sliding contact **302** in place during reflow. In particular, the restraining element **314** is adapted to secure the sliding contact **302** in a state that prevents it from sliding down the channel **310** during reflow. For example, the restraining element **314** may enable keeping the spring element in a compressed state even with the solder or other material holding the sliding contact **302** to the electrodes **304**, **306** and heater element **308** melts, thereby preventing the spring element from expanding and pushing the sliding contact **302** down the channel **310**.

The restraining element **314** may made of a material capable of conducting electricity. For example, the restraining element **314** may be made of copper, stainless steel, or an alloy. The diameter of the restraining element **314** may be sized so as to enable blowing the restraining element **314** with an arming current. The restraining element **314** is blown, such as by running a current through the restraining element **314**, after the device **300** is installed. In other words, sourcing a sufficiently high current, or arming current, through the restraining element **314** may cause the restraining element **314** to open. In one embodiment, the arming current may be about 2 Amperes. However, it will be understood that the restraining element **314** may be increased or decrease in diameter, and/or another dimension, allowing for higher or lower arming currents.

To facilitate application of an arming current, a first end **314***a* and second end **314***b* of the restraining element **314** may be in electrical communication with various pads disposed about the housing. The first end **314***a* may be connected to the electrode **316**, which corresponds to the electrode **128** in the embodiment of FIGS. **1**-**2**. Referring to the embodiment of FIGS. **1**-**2**, the electrode **316** (or **128**) is in electrical communication with the terminal **206**. The second end **314**_b_ may be connected to the sliding contact **302**. The arming current may be supplied to the electrode **316** through terminal **206**.

Described below is an exemplary process for installing the three-function reflowable circuit protection devices described herein. The circuit protection device is placed on a panel. Solder paste may be printed on a circuit board before the circuit protection device is positioned. The panel, with the circuit protection device, is then placed into a reflow oven which causes the solder on the pads to melt. After reflowing, the panel is allowed to cool.

An arming current is run through pins of the circuit protection device so as to blow the restraining element. Referring to FIG. **2**, sufficient current, for example, 2 Amperes, may be applied to the terminal **206**, which is electrically connected to the restraining element, so as to blow the restraining element and allow the spring element to push the sliding contact in the open position under one of the three conditions described herein. Blowing the restraining element places the circuit protection device in an armed state.

FIGS. **4-6** are a schematic representation of an exemplary battery pack circuit **400** to be protected by a circuit protection device. In the example shown in FIGS. **4-6**, the circuit **400** utilizes the circuit protection device **300** of FIG. **3**. For the sake of explanation, the circuit protection device **300** can be positioned in series with two terminals **402**, **404** connected to circuit components to be protected, such as one or more FETs. It will be understood that the circuit protection device **300** may be used in other circuit configurations. The heater element **308** is electrically connected to an activation controller **406**.

FIG. **4** shows the circuit protection device **300** before the restraining element **314** is blown. FIG. **5** shows the circuit protection **300** after the restraining element **314** is blown. Further, in FIGS. **4-5** the sliding contact **302** is in the closed position, thus bridging and providing an electrical connected between electrode **304**, electrode **306**, and electrode **308** (i.e., the heater element). FIG. **6** shows the circuit protection device **300** in the open position in which the electrical connected between the electrodes **304**, **306**, **308** is severed, such as after a fault condition (over current or over temperature) is detected, or after an activation signal by the activation controller **406**.

FIG. **7** shows another embodiment for the substrate **700** of a three-function circuit protection device. In this embodiment utilizes an embedded resistor concept used in PCB construction. The substrate **700** includes a top PCB layer **702** and a bottom PCB layer **704**. The top PCB layer **702** includes pads **706**, **708** for electrical connection to patterned electrodes **710**, **712**, respectively, in the bottom PCB layer. The top PCB layer **702** also includes a via connection **714** to the heater element **716** that is laid up into the substrate **700** during a PCB process. In this example, the heater element **716** is a thin-film resistor or other heating device. With the film in this embodiment, the resistance path is transverse to the plane of the film.

FIGS. **8-9** show top and bottom views, respectively, of another embodiment of a three-function reflowable circuit protection device **800**. In the circuit protection device **800**, the spring element **802** is located in the cover **804** instead of within the substrate **806**. The cantilever portion **808** of the sliding contact **810** extends up into the cover **804** instead of down into an opening in the substrate **806**. The substrate **806** in FIGS. **8-9** need not be patterned to include an opening that receives the cantilever portion **808** of the sliding contact **810**.

The underside of the cover **804** (shown in FIG. **9**) includes a depression, or channel **902**, into which the cantilever portion **808** may be inserted, and through which the cantilever portion **808** may slide when the solder holding the sliding contact **810** to the electrodes of the substrate **806** melts.

The spring element **802** may be installed into the cover **804** through a side of the cover **804**. A cap **812** may then be inserted into the side of the cover **804** to hold one end of the spring element **802** in place such that when the spring element **802** expands under of the activation conditions described herein, the resulting force will push the cantilever portion **808** down the channel **902**. The cap **812** includes a protrusion **814** that is tapered on one end and normal to the length of the cap **812** on the other end. In this manner, the cap **812** may be inserted into a hole on the side of the cover **804** with a snap-fit connection. It will be understood that other methods may be used to insert the spring element **802** into the cover **804**.

While the three-function reflowable circuit protection device has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the claims of the application. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from its scope. Therefore, it is intended that the three-function reflowable circuit protection device is not to be limited to the particular embodiments disclosed, but to any embodiments that fall within the scope of the claims.

We claim:

1. A three-function reflowable circuit protection device comprising:

a substrate comprising a first electrode, a second electrode, and a heater element, the heater element receiving an activation control current;

a sliding contact positioned on the substrate at a first location and having a cantilevered portion extending into an opening in the substrate for restricting movement of the sliding contact to a linear path, wherein at the first location the sliding contact is connected to, and provides a conductive path between, the first electrode, second electrode, and the heater element via a sensing element;

a spring element biasing the sliding contact along the linear path to a second location upon loss of resilience of the sensing element, wherein at the second location the sliding contact does not provide a conductive path between any of the first electrode, second electrode, and the heater element, and

a restraining element securing the sliding contact at the first location during a reflow process,

wherein the sensing element loses resilience upon detection of any one of the following activation conditions:

an over current condition;

an over temperature condition; and

the activation control current received by the heater element, and

wherein application of an arming current through the restraining element causes the restraining element to break and place the circuit protection device in an armed state.

2. The circuit protection device of claim **1**, wherein the sensing element comprises a material that melts at a threshold temperature.

3. The circuit protection device of claim **1**, wherein the heater element is one of a thin-film resistor and a positive temperature coefficient device.

4. The circuit protection device of claim **1**, wherein the spring element exerts a force on the cantilever portion.

5. The circuit protection device of claim **4**, wherein when the sensing element loses resilience, the spring element moves the sliding contact to the second location by pushing the cantilever portion.

6. The circuit protection device of claim **4**, wherein when the sensing element loses resilience, the spring element moves the sliding contact to the second location by pulling the cantilever portion.

7. The circuit protection device of claim **1**, wherein the over current condition at which the spring element moves the sliding contact to the second location is detected when a current passing between the first and second electrodes exceeds a threshold current and causes the sensing element to melt.

8. The circuit protection device of claim **1**, wherein the over temperature condition at which the spring element moves the sliding contact to the second location is detected when an ambient temperature surrounding the circuit protection device exceeds a threshold temperature.

9. The circuit protection device of claim **1**, wherein the heater element heats up to a melting point of the sensing element upon receipt of the activation control current.

10. The circuit protection device of claim **1**, wherein the substrate comprises mounting pads allowing surface mounting of the circuit protection device to a panel.

11. A reflowable circuit protection device comprising:

a substrate comprising a first electrode, a second electrode, and a heater element between the first and second electrodes;

a sliding contact positioned on the substrate location and having a cantilevered portion extending into an opening in the substrate for restricting movement of the sliding contact to a linear path, wherein:

at a first location on the substrate the sliding contact provides a conductive path between the first electrode, second electrode, and the heater element,

at a second location on the substrate the sliding contact does not provide a conductive path between any of the first electrode, second electrode, and the heater element;

a spring element biasing the sliding contact to the second location along the linear path upon detection of any one of the following activation conditions:

an over current condition;

an over temperature condition; and

the activation control current received by the heater element, and

a restraining element securing the sliding contact at the first location during a reflow process,

wherein application of an arming current through the restraining element causes the restraining element to break and place the circuit protection device in an armed state.

12. The circuit protection device of claim **11**, further comprising a housing that encases the substrate, sliding contact, and spring element.

13. The circuit protection device of claim **12**, wherein a height of the housing that encases the substrate, sliding contact, and spring element circuit is less than or equal to approximately 1.5 mm.

14. The circuit protection device of claim **12**, wherein a length of the housing that encases the substrate, sliding contact, and spring element is less than or equal to approximately 6.0 mm.

15. The circuit protection device of claim **12**, wherein a width of the housing that encases the substrate, sliding contact, and spring element is less than or equal to approximately 3.8 mm.

16. The circuit protection device of claim **11**, wherein the heater element comprises one of a thin-film resistor and a positive temperature coefficient device.

17. The circuit protection device of claim **11**, wherein the substrate comprises mounting pads allowing surface mounting of the circuit protection device to a panel.

18. A reflowable circuit protection device comprising:

a substrate comprising a first electrode, a second electrode, and a heater element, the heater element receiving an activation control current;

a sliding contact positioned on the substrate location and having a cantilevered portion extending into an opening in the substrate for restricting movement of the sliding contact to a linear path, wherein:

at a first location on the substrate the sliding contact provides a conductive path between the first electrode, second electrode, and heater element, and

at a second location on the substrate the sliding contact does not provide a conductive path between any of the first electrode, second electrode, and heater element; and

a spring element exerting on the sliding contact a force directed along the linear path,

wherein at the first location the sliding contact resists the force exerted by the spring element until detection of any one of the following activation conditions:

an over current condition;

an over temperature condition; and

the activation control current received by the heater element, and

wherein upon detection of any one of the activation conditions, the force exerted by the spring element moves the sliding contact to the second location, and

a restraining element securing the sliding contact at the first location during a reflow process,

wherein application of an arming current through the restraining element causes the restraining element to break and place the circuit protection device in an armed state.

19. The circuit protection device of claim **18**, wherein the over current condition at which the spring element moves the sliding contact to the second location is detected when a current passing between the first and second electrodes exceeds a threshold current and causes the sensing element to melt.

20. The circuit protection device of claim **18**, wherein the over temperature condition at which the spring element moves the sliding contact to the second location is detected when an ambient temperature surrounding the circuit protection device exceeds a threshold temperature.

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